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Discussions

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Interactive
comment

Interactive comment on "Ice nucleating particles measured in Swiss alpine snow samples are spatially, temporarily and chemically heterogeneous" *by* K. P. Brennan et al.

Anonymous Referee #1

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In this manuscript Brennan et al. present results from INP measurements of snow samples collected at different locations, altitudes, times, and depth in the Swiss Alps. They found highly variable INP concentrations and used the data to generate a parameterization for the calculation of cloud glaciation temperatures.

The authors generated a very rich, unique and great data set of INP concentrations of 88 snow samples. This dataset is sound and the study is suited to the scope of the journal. The presented results are important for the ice nucleation community and can be useful for modelers. The experiments were well designed and were properly executed. I recommend publication after the following points have been addressed:

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Discussion paper

I do not understand how the authors come to the result and very prominent message presented in the title that the INP in the Swiss Alps are chemically heterogeneous. I cannot find experiments and results in the manuscript that support this message. Filtration of the samples just allows an estimation of the (physical) size of the INP. Determination of the pH, conductivity and TOC of the snow samples does not give information on the chemical composition of the INP within the snow.

In the abstract the authors write that they compared the INP concentrations with meteorological parameters. Which parameters were used? Where are the results?

Moreover, the authors highlight an alternative plotting method of INP data in the abstract. I wonder if there is another difference to Polen et al, 2018, than an extension to another sample type (field). Both studies used the same kind of data (freezing temperatures and frozen fractions). The sample type (field or laboratory) seems to be a secondary aspect, which does not explain why this is highlighted in the abstract.

Furthermore, the mixed use of "snow" (e.g., P7L25), "snowwater" (e.g., P1L25), "meltwater" (e.g., P8L26), "melted snow samples" (e.g., P7L18), "snow meltwater" (P2L50) and "snowmelt" (e.g., P8 Table 2 caption) for the same samples in this manuscript is confusing and leads to the impression that different types of samples have been analyzed e.g., P12L26/27 "..was observed for meltwater sampled on April 4,. . ." and 4.2 "Heterogeneity of ice nucleating particles in meltwater".

P2L28: "Soluble INPs have also been shown to be efficient INPs if they contain extracts from plant-based material,. . ." Please correct this statement. A soluble INP cannot contain "extracts". Moreover, for example fungal INP can nucleate at higher temperatures than plant INP (see cited reference Pummer et al 2015, ACP).

P4L18: Please add here the information that the tubes were sterile.

P5L3: The authors should either add some information on how the snow was compacted and/or refer to the supplement where this information is given. Did the authors

check with so called "handling blanks" that no contaminations occurred during sampling, compaction, transport and further handling of the tubes?

P5L8: How did the authors avoid cross-contamination when taking the depth profile samples? Was the shovel cleaned between the different sampling sites? How was made sure that no surface or "upper layer" INP were brought into the lower snow layers during shoveling?

P5L35: Why are INP concentrations not available for all temperatures? A short explanation should be added here.

P5L38: Can the authors explain why the first two frozen wells were considered as contaminations? I would expect a higher risk of contamination with lower T INP if there is a contamination as shown by the three samples which overlap with the water control.

P6L8: The authors write that they used the "data without trimming" although it was described in the paragraph before (P5L40) that the data were trimmed and the first two wells were excluded. This is confusing and needs clarification.

P6L8: Please cite the final paper of Polen et al. (published in AMT in Sep 2018). Polen, M., Brubaker, T., Somers, J., and Sullivan, R. C.: Cleaning up our water: reducing interferences from nonhomogeneous freezing of "pure" water in droplet freezing assays of ice-nucleating particles, Atmos. Meas. Tech., 11, 5315-5334, https://doi.org/10.5194/amt-11-5315-2018, 2018.

Figure 3: This figure and caption is not clear. Two locations are displayed as refreezing's and three other locations as triplicates. If refreezing and triplicates are different things one should compare the same samples/locations. Based on the caption "refreezing triplicate data" refreezings and triplicates seem to be actually the same i.e., refreezing of triplicates? Please clarify. Omit "Finally" in the caption.

P7L27: Please clarify. In L26 it is said that filter with pore sizes 0.2 and 0.45 μm were used to determine the size of the INP. But then results of a 0.7 μm filtration and

0.02 are presented too. It would help to restructure the paragraph about the filtration experiments and put the filtrations in a more logical order. Please correct "Tests done with a 0.7 μm glass fiber filters". Omit the "a" or the "s" from "filters".

P7L32: Omit "purchased through" - superflous

P7L35: Please introduce "SA water" when used first.

Table 2: " and the following...". Nothing follows, thus omit.

P9L21: Omit "in size". "smaller than 0.2 μm" is sufficient.

P9L29: It would help to mention the sources of such proteinaceous INP such as fungi and plant pollen (see cited reference Pummer et al. 2015, ACP).

Figure 5: "filter size"→ "pore size", missing spaces before μm, " were filtered at 450 , 200 and 20 nm"..." → stay with μm, "filtered through";

P10L19: The header "Sampling site characteristics" sounds more like a description of the sampling sites and thus does not fit to the subsections and results presented in this section.

Figure 7/8: Is there a difference between TFrz as used here and Temperature used in Figure 3, which is the same type of plot?

Figure 13: I am not a cloud expert, but wonder if it would be better to use "frozen fraction of could droplets" instead of "frozen cloud fraction" as the INP concentrations are known.

P17L10: The subsection "4.2. Heterogeneity of ice nucleating particles in meltwater" is more or less redundant to the results and discussion already presented in "3.3. Sampling site characteristics" and seems not fit as a subsection in "4. Atmospheric implications". The sections 3.3. and 4.2 should be merged in 3.3 with a new heading, as suggested above.

Figure S1: Based on the information given in the method section (P4L23) water from Sigma Aldrich was used as control. What is, with only one type of water, the difference between the untreated tube and SA (I assume this means Sigma Aldrich water) reference? Moreover, the results of the methanol, acetonitrile and HCl washings as listed on P4L21 are not presented in Figure S1, but instead there is a Milli-Q wash presented. Figure and corresponding text should be checked for consistency and completeness.

Figure S2: "The grey shaded area..." In my version there is no grey shaded area in this figure. The authors might want to check this.

Figure S3: "Size dependency" -> "size determination"; "filter size" -> e.g., "pore size", " were filtered at 450 , 200 and 20 nm"..." → stay with μm, "filtered through"; omit " The T10 version..." as this is the T10 version.

Technical corrections

There are numerous other typos and inconsistencies throughout the manuscript. Many of those errors should have been caught by careful proofreading. I list the issues that caught my eye but I advise the authors to recheck their manuscript carefully to catch all of those typos.

Mixed use of l and L for Liter in text and figures. Mostly L is used but l is used in P1L15, Fig 2, P5L31, Fig 4, Fig 6, Fig 9.

Missing spaces (Table 1 – 10m, P5L31-0.05ml, Fig 5, Fig 13, Table S1, SuppP5L7, Fig S3).

Inconsistent format/symbols: T50 (Text vs Table S1, caption Table 2), μ (Text, Fig 5, Fig S3) vs uS (Fig 6, Fig 9).

Figures have partly axes with °C and K (Fig. 11, 13), partly only with °C (Fig 12).

Axis title capitalization (Fig 13) vs not capitalized (Fig 11).

Table 1: The "altitude" within the brackets should be "latitude".

P8L31: "for" all types.

Figure 4 caption: "conductivity TOC"→ "conductivity. TOC"?

P10L25: "display"->"displays".

Figure 12: Emty [] on the y-axis.